Using the Space Glove to Teach Spatial Thinking

BY PETER LORD

I was standing in the dining room of a rambling white Victorian on Mount Desert Island, home to Maine's Acadia National Park. Arrayed before me on a massive wooden table lay an antique sewing machine, an improvised pressure test stand, a glass vacuum chamber, and an immense collection of gloves and fingers. I had driven across this mountainous island as an engineer and curious educator hoping to get my hands on Peter Homer's Centennial Challenge–winning astronaut glove.

Photo courtesy Peter Lord

Alexis of Pemetic Elementary School tries on one of Peter Homer's "failed" glove designs.

I'd come to Mount Desert Island to found the Island Astronomy Institute, in part to fill the space sciences gap in the island's schools with a grant from NASA's Maine Space Grant Consortium. News of Peter's prize-winning astronaut glove had spread across the island's towns like wildfire, in part because this type of engineering simply does not happen here.

My own experiences designing and building commercial spacecraft, including the three satellites of the Sirius Satellite Radio constellation, made it easy to admire Peter's mechanical aptitude. My first patent grew out of multiple failures. I was one of three engineers assigned to solve a high-profile, on-orbit performance issue. Fabricated with our own hands from custom composite materials, our first full-scale engineering model of a 2.4-meter "self-supporting aperture cover" was a total failure. The second model was almost a complete failure, but we were fast learners. Our third attempt is now used on dozens of satellites.

As Peter unfolded his story, I couldn't help but smile. Here was a road I had traveled many times but had never seen portrayed with such clarity. Each piece of glove Peter picked up spoke volumes about the creative process of planned failure and incremental success. On the table lay the physical evidence of insight, perseverance, and, perhaps more than anything else, the ability to visualize precisely what was required to arrive at a winning design by the competition deadline. I was impressed and excited about the educational possibilities.

The way of thinking that Peter so clearly embodies is reflected in the Institute's mission to promote astronomy as a stimulating educational and cultural activity for people of all ages. The full significance of this way of thinking was brought to my attention in 2006 by a National Academy of Sciences report called *Learning to Think Spatially*. The report recognizes the ability to visualize and manipulate objects in space as a poorly understood, previously unrecognized "blind spot" in the nation's educational system. It describes spatial thinking as a fundamental cognitive process "integral to the everyday work of scientists and engineers that has underpinned many scientific and technical breakthroughs." I knew from my own experience that this was a nonverbal skill, a unique kind of knowledge that, once grasped in a flash of understanding, becomes as natural as riding a bike.

The Island Astronomy Institute was founded on the proposition that astronomy provides an efficient, engaging way to teach advanced forms of thinking now characterized by the National Academy of Sciences as enabling deep understanding across the wide spectrum of knowledge-intensive fields. Advanced spatial thinking allows experts to conceive of and express highly abstract concepts through a language of spatially conceived analogies and metaphors.

THE CHALLENGE OF EXTENDING STUDENTS' SKILLS IN SPATIAL THINKING TO ASTRONOMICAL SCALES WAS THE CENTRAL FOCUS OF OUR K–8 CURRICULUM DEVELOPMENT.

The ability to envision a physical perspective outside our own bodies comes into play when we recognize our own image in a mirror. Expanding this spatial skill across broader dimensions of time and space is essential to developing deep astronomical knowledge. It is one thing to state that Earth revolves around the sun; it is quite another to stand under a noon-day sun and point to where the earth you are standing on will be in three months.

Ironically, attention to these critical spatial skills is usually limited to the first years of elementary school. Some people have the ability to mentally rotate our sense of physical orientation to the East, West, North, and South without thinking, but many don't. The process is so instinctive in those who possess it, we describe it as a "sense" of direction. Spatial concepts are deeply rooted in our most basic perception of our physical surroundings. Several college students in our philosophy of astronomy class reported feeling the earth move under their feet as they repeated Galileo's observations through a telescope; was Jupiter moving, or was it Earth?

The challenge of extending students' skills in spatial thinking to astronomical scales was the central focus of our K–8 curriculum development. When the project's lead teacher requested a curriculum that cumulatively built on each prior year's learning in a spiral fashion, I knew exactly what the school was asking for. Second and third graders began by noticing the cyclical patters that the sun, moon, and stars make in the sky. Fourth graders explored the phases of the moon by taking turns modeling and sketching them in their classroom and then comparing them to the real sky. Sixth graders used real telescopes to observe a moving model of our solar system and walked a scale model of the planets' orbits. The curriculum is designed to expand students' capacity to visualize space in a hierarchical fashion that asks them to imagine themselves from a broader number of spatial perspectives through hands-on activities.

The "situational awareness" Peter's story describes is a hallmark of high-performance engineering and innovation. Keeping in mind the potential outcomes of multiple paths of pursuit from multiple perspectives while keeping track of their relative merits and performance requirements is a demanding spatial task.

What made it possible for Peter to transform the failure of his first glove into triumph was the mental space in which that failure provided exactly the information needed for a new breakthrough. In at least two cases, Peter could immediately "see" the full implications of what his hands were telling him. He tells the story of how putting his hands in a Phase VI astronaut glove instantly transformed his understanding of the glove challenge. Six months into his development, the failure of circumferentially wrapped cords to produce a sufficiently flexible glove again forced him to abandon his assumptions. His situational awareness was so clear and compelling it became a gut-level response. Peter's finely developed spatial skills enabled him to almost instinctively focus his full energy on a carefully constructed set of experiments. The finger's ability to sense pressure, force, and work gave him the immediate feedback required to solve this one central problem. Once properly understood, his failure quickly led to the magical "Aha!" moment of discovery; the rest is history.

Peter worked in the kind of information-rich, hands-on environment so essential to science education. At the request of local teachers, Peter and I hauled his collection into class to test my belief in the glove's educational potential. Peter and I shared his engineering process, complete with failures and the principles of pressure, force, and work at play in the successful design. Then we gave students the chance to get their hands on it all, letting them develop their own spatial understanding. The feedback from the students and teachers was that the glove was an instant hit: they really "got" it.

Just as children need opportunities to develop hands-on understanding, engineers need to explore new possibilities through incremental hands-on failure. High-performance innovation is all about learning to make maximum use of thinking spatially to direct this process. Peter Homer's glove also reminds us that efficient engineering decisions need to be made as close to the hardware as possible. Whether we're doing hands-on education or hands-on engineering, it is when we trust in our ability to "feel our way" through failure that we reach our highest potential. ●

PETER LORD is executive director of the Island Astronomy Institute and a consulting senior satellite systems engineer with Stellar Solutions.